VOLUME LX NUMBER 1 WHOLE NUMBER 350

THE JOURNAL
OF
THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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PUBLISHED MONTHLY
(*Ten numbers per year*)

January, 1946

PRINTED FOR THE SOCIETY
TORONTO: 198 COLLEGE ST.

THE JOURNAL
OF
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Address of Editors: David Dunlap Observatory, Richmond Hill, Ont.

Business correspondence, remittances, etc., should be addressed to J. H. Horning, Treasurer of the Society, 198 College Street, Toronto 2B, Ontario.

$2.00 per annum. Single numbers, 25 cents.

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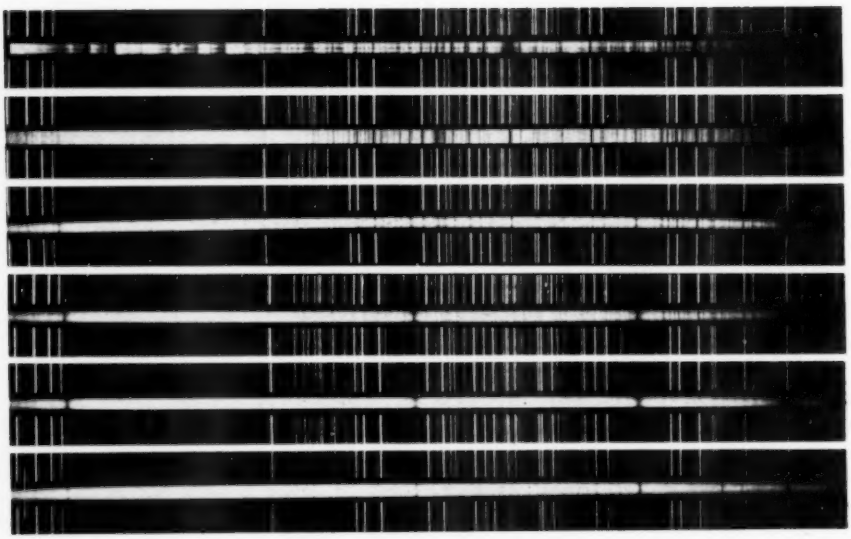
PRINTED IN CANADA

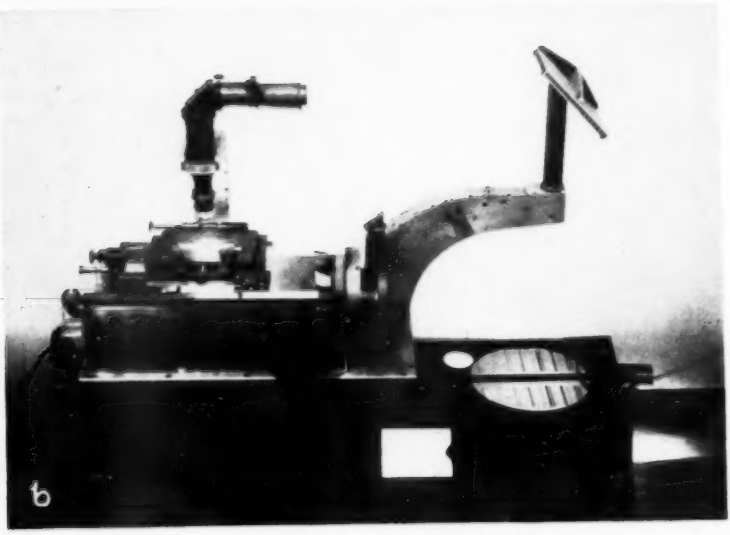
PLATE I



REPRESENTATIVE STELLAR SPECTRA FOR RADIAL VELOCITY

Determination: χ Aurigae (B 1); 52 Pegasi (F 0_n); χ Leonis (F 0); B.S.C.4345 (G 0); α Bootis (K 0); 45 Arietis (M 6).

PLATE II



(*a*) Standard Gaertner Measuring Machine
(*b*) Projection Measuring Machine

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THE DETERMINATION OF STELLAR RADIAL VELOCITIES

By R. K. YOUNG

(With Plates I, II)

PROPER MOTIONS OF THE STARS

THE early observations of astronomy relate almost entirely to the planets. The stars were merely fixed points of reference, which aided the observer to follow the motion of the planets, moon and sun. This outlook continued up to the time of Flamsteed (1646 - 1740). At this time, if astronomers had been asked if the stars were really fixed as the name "fixed stars" implied, many would have conceded that they might be in motion but that the motions were too small to detect. Edmund Halley was apparently the first to discover that some stars had actually shifted their positions in the sky. In 1718 he announced that Sirius, Aldebaran, Betelgeuse and Arcturus were in different positions from those given in Ptolemy's catalogue, which was based on observations made sometime before the birth of Christ.

The observation for the motion of the stars progressed very slowly at first because at that time there were no accurate early observations with which to compare the more recent accurate determinations. The observations of Bradley were made at Greenwich between 1750 and 1760. He observed with remarkable accuracy several thousand stars, which served as a starting point; and the reobservation of them in the intervening years has yielded the motions of all the naked-eye stars and many others. The

Yale catalogue contains the motions of over 33,000 stars. The apparent shifting of the position of a star on the celestial sphere is expressed as so many seconds of arc per year and is known as the *proper motion* of the star.

We cannot doubt that all the objects which constitute our sidereal system—stars, nebulae, dark bodies and our own sun—are in motion according to some law. The ferreting out of these motions constitutes a very important part of the study of astronomy.

Motions in the Line of Sight

Proper motions taken alone give a very imperfect picture of the motion of the stars. This motion is at right angles to the line-of-sight relative to the sun and will be influenced by the distance of the star from us. To get a complete picture we must know how fast the star is moving in kilometers per second and the direction in space in which it is moving. This can be computed only if, in addition to the proper motion, we know how far the star is away, how fast it is moving in the line-of-sight and how fast our sun is moving and in what direction. As stated above, we know the proper motions of over 30,000 stars. The observations of the velocities in the line-of-sight, called the *radial velocity*, have thus far been made for less than 10,000 stars. It is because of this disparity that the observation of radial velocities is one of the important needs of astronomy.

Radial Velocities and Stellar Spectra

The radial velocities of the stars are determined from the observation of their spectra. When the light from a star is passed through an instrument known as a spectrograph, it is drawn out into a band of coloured light, red at one end and shading through the colours orange, yellow, green, blue and violet toward the other. The diagrammatic arrangement of such an instrument is shown in figure 1.

The light of the star, after passing through the telescope, is focused on the slit S, which (in the Dunlap Observatory spectrograph) is a small rectangular opening about .002 inch wide and .020 inch long. After passage through the slit, the light from the star diverges at the angle b, which is the same as the angle a at

which it was converging from the telescope. Then it continues and it falls on the lens L_1. This lens renders the rays parallel and they are then received by a prism of glass P, two or three inches high and usually with a section in the shape of an equilateral triangle. The rays of light of various colours are bent to different degrees by the prism, the red rays being bent the least and the violet the most; and the various beams, parallel for each colour, are received by the lens L_2 and are focused on the photographic plate $V\ R$. The violet light comes to a focus at V and the red light comes to a focus at R. When the plate is developed there will be a darkened band on the plate of length $V\ R$, depending on the kind of glass, and its width will be dependent on the length of the slit.

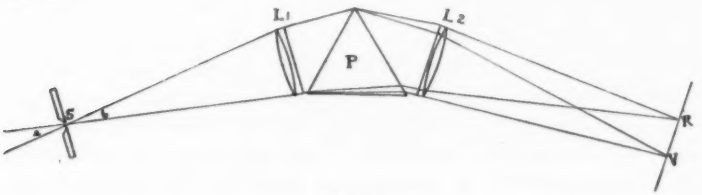


FIG. 1

We may regard this band as made up of an infinite number of images of the slit placed side by side to piece out into the length $V\ R$. Starting at V, we have an image in the violet light .002 inch wide and .020 long, next to it a second image in light not quite so violet in colour, then another still less violet until we pass to blue images, then orange, etc., to finally red. It has been shown in the study of light that it is a wave-motion and that the colour of the light depends on the length of the wave. Light at the violet end of the spectrum has a wave-length approximately .00004 cm. long; while red light has a wave-length about .00008 cm. long. The intermediate colours have wave-lengths between these two extremes. We may, therefore, regard the position on the photographic plate between V and R, as measuring the wave-length of the light at that point. Of course, it is not of necessity true that the displacement from V toward R will be proportional to the change in wave-length and indeed such is not the case. We have to find out what this relation is.

The spectra of six stars are shown in Plate I. These have been enlarged for reproduction. The entire spectrum in each case is about 1/8 inch wide and 5 inches long. The originals are about one inch long and 1/50 inch wide. The wave-length of the light at the left is about .000038 cm. for the extreme violet and at the other end it is about .000050 cm. This end is still in the blue or blue-green. The plates used were sensitive to the blue end of the spectrum only.

It will be noticed also that the spectrum is not continuous from one end to the other but that certain colours or wave-lengths are missing. In the first spectrum, there are comparatively few gaps. These are more noticeable in the second and third while in the fifth and sixth the gaps constitute a large part of the spectra. To understand this fully, we must know a little more about spectra in general.

The kind of spectra one will photograph on the plate at *V R* depends on the nature of the light which is illuminating the slit at *S*. When in the laboratory a solid, a liquid, or a gas at very great pressure, is heated to incandescence, the light which comes from it will give a *continuous* spectrum. This means that all the colours or wave-lengths will be present and there will be no gaps. The light from the gas from a chemical element when heated, the gas being at low pressure, will give a spectrum consisting of a number of *separate* wave-lengths. These wave-lengths, represented by bright lines, are characteristic of the particular element. Iron vapour gives one set, copper another, and so on through the range of chemical elements. If however the light from an incandescent solid passes through a gas at lower temperature and is allowed to fall on the slit, the spectrum will be *continuous* save for wave-lengths which will be missing at the exact places where the bright lines would have been, had the gas been emitting its bright-line spectrum. This is called the *absorption* spectrum for that gas.

Applying these results to stellar spectra, we conclude that the spectra of the stars show that the light-giving "surface" of the star is constituted either as an incandescent solid, a liquid, or a gas at high pressure, and that the outer atmospheres of the stars contain the gases of various elements giving rise to various absorption lines. The lines of all the elements have been studied in the laboratory and co-related with lines seen in stellar spectra, so that we confi-

dently assert that the same elements are present in the stars that we find on the earth.

Looking at Plate I again we see that in each case, the spectrum is flanked, above and below, by a series of bright lines. This is the iron arc spectrum. It was produced at the time the stellar spectrum was being made by allowing the light from an iron arc to shine for a few moments on the slit of the spectrograph. The part of the slit where the light from the star fell was covered, so that the iron arc spectrum would not cross that of the star. In every case the iron arc spectrum is identical but the stellar spectra in the six cases shown in this plate all differ from one another. Spectra are classified according to the lines shown in their spectra and are distinguished as B, A, F, G, K, M, N, O, etc. The particular letters selected have arisen in a rather haphazard manner and follow no particular order.

The exact aspect of the spectrum of a star depends on many factors. They may differ in the absorption lines, or in some cases bright lines shown; the extent of the continuous spectrum; the strength or intensity of the various lines; or in the exact position in which the lines are seen.

Doppler's Principle

It was in 1842 that Doppler, from considerations that light was a wave motion, predicted that if the star was moving toward us, the lines of its spectrum would be shifted toward the violet from their normal positions; and, on the other hand, a shift toward the red would indicate a velocity of recession of the star with respect to the observer. It makes no difference whether the source or the observer is in motion. A red shift indicates that the distance between the observer and the star is increasing while a violet shift indicates that the distance is decreasing. For this reason velocities of recession are given the positive sign and velocities of approach the negative sign. Doppler's principle, as it is now called, was further studied by Fizeau in 1848 and he gave the numerical relationship between the magnitude of the shift of the lines and the velocity.

This relation may be stated:

$$\frac{\text{Velocity of recession}}{\text{Velocity of light}} = \frac{\text{Change in wave-length}}{\text{Wave-length}}.$$

In symbols this is written

$$\frac{V}{v} = \frac{\Delta\lambda}{\lambda},$$

V standing for velocity of recession, negative if an approach,

v velocity of light,

$\Delta\lambda$ change in wave-length,

λ wave-length of line under measurement.

In order to make the equation true V and v must be in the same units and λ and $\Delta\lambda$ in the same units but not necessarily in the units of v and V. It is customary to express v and V in kilometers per sec., and λ and $\Delta\lambda$ in angstrom units. An angstrom unit is 10^{-10} of a meter (or one ten-millionth of a millimetre).

It is interesting to test this equation numerically in order to see the magnitude of the displacements of the spectrum lines we may expect to obtain. Taking an arbitrary velocity of recession of 1 km. per sec. and λ as 4500 angstrom units, the velocity of light being 299,860 km. per sec., gives $\Delta\lambda$ .015 angstrom units. Now in Plate I, the spectrum from λ 3800 — λ 5000 is about 5 inches in length. Consequently, on this plate, a velocity of recession (or approach) of 1 km. per sec. would shift the lines about .00006 inch. On the original plate, from which the plate is enlarged, the shift would be less than .00002 inch.

Measuring the Photographic Plate

In order that such small quantities may be measured with any degree of accuracy, a very precise measuring device must be used. Plate II shows two forms of such machines. In (*a*) we see the measuring machine as developed by the Gaertner Scientific Corporation. The photographic plate is placed on the stage and can be lined up so that the length of the spectrum is parallel to a finely cut and ground micrometer screw, which when turned draws the plate under the view of a magnifying microscope. The power used is usually from 5 to 35 and the screw is guaranteed free from periodic and systematic runs greater than .00001 inch. In the instruments

used at the David Dunlap Observatory, the pitch of the screw is one-half millimetre and readings are made to .001 of a revolution, and all displacements and positions on the plate are recorded in revolutions. In (*b*) a somewhat different machine is illustrated. The plate is placed on the stage and an image of it projected on a white screen conveniently located on the table on which the machine rests. The plate is drawn beneath the projection system in which a fine micrometer wire is placed and its stationary image is projected on the spectrum. The advantage of this method to some is that it avoids the eye-strain of looking through a microscope for long stretches of time. Instead of reading the position of the plate on the screw head as in (*a*), an image of the graduations is also projected on the screen. In the illustration, this is shown as a small bright circle above and to the left of the image of the spectrum. The fine graduations are seen with difficulty in the picture.

With any given disposition of the plate on the above measuring instruments, we can determine the position of any point in the spectrum in terms of the reading on the micrometer screw. Before we can determine whether they are displaced from their normal positions either to the red or the violet, we must know the positions corresponding to zero velocity of the source. This is accomplished by photographing a comparison spectrum. In Plate I each star spectrum is flanked by the spectrum of iron. This is impressed on the plate by reflecting the light from an iron arc, by means of two small total-reflection prisms placed over the slit on each side of the portion of the slit through which the light of the star falls. Inasmuch as the iron arc is situated on the telescope, the lines will occupy the positions of zero velocity. The wave-lengths of several of these lines are labelled on the plate. The wave-lengths of all the iron lines have been carefully determined in the laboratory. Other elements besides iron could be used and sometimes are used. The iron arc, however, gives numerous well-defined lines throughout almost the complete range of the photographic region and is the source most frequently employed for the purpose.

It is necessary also to know the wave-lengths of the lines occurring in the stellar spectra. These rest on the wave-lengths determined in the laboratory. In the case of those stars which show rather few isolated lines, which can be identified with known

lines, the wave-lengths as determined in the laboratory are adopted. In the case of stars wherein the lines crowd one another, if laboratory wave-lengths are used, the radial velocity measured from the various lines will often be found inconsistent. This arises doubtless from the fact that in spectra made with such a short linear scale, many of the lines consist of "blends," whose intensities vary from star to star. Gradually a system of selection has been evolved and lines used for radial velocity determinations are those which experience has shown to give the most consistent results.

The International Astronomical Union has attempted to unify the practice of astronomers working in this field by publishing a system of recommended wave-lengths. A portion of this table is shown in Table I, with the micrometer settings for zero velocity when the spectra are taken with our one-prism spectrograph and 25-inch camera. Different camera lengths or different instruments would have other tables of settings but the wave-lengths used would be the same.

TABLE I.

Wave-length	Setting	*rVs*	Wave-length	Setting	*rVs*
3969.261	23.729		4250.465*	45.165	1070
4005.246	26.839		4254.348*	45.421	1073
4030.755*	28.970	903	4260.415*	45.818	1078
4030.755	28.970		4271.545*	46.541	1086
4033.073*	29.161	905	4282.622*	47.253	1095
4034.490*	29.277	905	4282.406	47.239	
4035.683*	29.375	906	4289.632*	47.700	1100
4063.635*	31.633	927	4307.914*	48.851	1115
4071.751*	32.276	933	4314.668*	49.271	1120
4071.740	32.275		4315.088	49.297	
4092.478*	33.894	949	4325.652*	49.949	1129
4118.549	35.879		4352.737	51.592	
4127.840*	36.574	976	4404.763*	54.637	1190
4191.555*	41.168	1025	4415.153	55.228	1199
4191.436	41.160		4427.312	55.913	
4202.042*	41.897	1033	4494.568	59.570	
4233.612	44.045				

The wave-lengths which are used in the star spectrum are marked "*". In the third and the sixth column, headed *rVs*, a

number is shown, which when multiplied by the found displacement in revolutions will convert this displacement into km. per second.

Using the Measuring Machine

In proceeding to measure a plate, it is clamped on the stage of the measuring machine and aligned, so that the length of the spectrum is parallel to the measuring screw. This may be tested by turning the screw a number of turns and watching the image of the spectrum in the field of view of the microscope. If it is parallel, it will remain in the same part of the field, but if it is not parallel, it will move up or down. Usually orienting screws are provided on the machine to shift the plate. A little manipulation obtains the desired adjustment. A spider line in the microscope is adjusted till it lies along the comparison lines and the star lines and when the instrument has been carefully focused measurement is ready to begin. Settings are made on the comparison lines and the star lines in succession, usually beginning at the violet end of the spectrum. The plate is placed so that the violet end is to the observer's left in the eye-piece and turning the screw to the right advances the plate toward the red end of the spectrum. Usually a number of settings is made on each line and the mean taken mentally and the mean alone recorded. When the red end of the spectrum has been reached, the plate is reversed on the measuring engine and the same lines measured in the reverse direction. This is essential if accurate results are to be expected. Almost all measurers have a personal equation in attempting to bisect a line and will either consistently set too much to the left or to the right. By turning the plate and making the measures in a reverse direction, this personal equation is largely eliminated. Table II shows the results for plate number 9617 measured by Miss R. J. Northcott. The first three columns give the wave-lengths of the lines and the micrometer settings direct and reverse. In the wave-length column, the wave-lengths are recorded in whole numbers only, because identification with the lines in Table I is all that is required. For the same reason the whole revolutions of the micrometer settings are not recorded. The numbers given in these columns are the fractional part of the revolution. The whole number of revolutions may be obtained by identifying the lines in

Table I. Comparing the observed settings in the comparison iron spectrum with those given in Table I, we find that they do not agree. The differences are shown in the first entry in column five.

TABLE II.

Julian Day 2431042.619 — Date, Nov. 14, '43 — G.C.T. $2^h\ 52^m$ — hour angle, $0^h\ 48^m$ W. Star, H.D. 1419 — Type K 0 — Plate No. 9617 — Measured by R. J. Northcott.

Wave-length	Micrometer		Mean	Corrections		Correct reading	Disp. in Rev.	*r Vs*	Velocity km./sec.
	Direct	Reverse							
3969	727	271	728	+01					
4005	831	166	832	+07					
4030	982	016	983		11	994	+024	903	+21.7
4030	956	040	958	+12					
4033	181	817	182		11	193	+032	905	+29.0
4034	301	698	302		12	314	+037	905	+33.5
4035	394	598	398		12	410	+035	906	+31.7
4063	660	347	656		16	672	+039	927	+36.2
4071	292	712	290		17	307	+031	933	+28.9
4071	256	742	255	+20					
4092	910	092	909		21	930	+036	949	+34.2
4118	854	143	856	+23					
4127	577	422	578		25	603	+029	976	+28.3
4191	172	836	168		34	202	+034	1025	+34.8
4191	126	874	126	+34					
4202	892	107	892		36	928	+031	1033	+32.0
4233	004	995	004	+41					
4250	150	849	150		42	192	+027	1070	+28.9
4254	401	599	401		43	444	+023	1073	+24.7
4260	802	196	803		43	846	+028	1078	+30.2
4271	537	468	540		45	585	+041	1086	+44.5
4282	236	762	237		47	284	+031	1095	+33.9
4282	195	803	196	+43					
4289	682	321	680		47	727	+027	1100	+29.7
4307	830	175	828		50	878	+027	1115	+30.1
4315	254	753	250		51	301	+030	1120	+33.6
4315	245	754	246	+51					
4325	923	080	922		53	975	+026	1129	+29.4
4352	536	466	535	+57					
4404	600	405	598		65	663	+026	1190	+30.9
4415	187	812	188		67	255	+026	1199	+32.4
4427	845	158	844	+69					
4494	492	509	492	+78					

Mean velocity from 21 lines + 31.38 with a probable error 0.6 km.

One unit in the third place of a revolution has to be added to the observed setting for the line 3969 to reproduce the tabular value and the amount which must be added to do this gradually increases as we pass to the red end till at line 4494 it reaches the value 78 in the third decimal place. This discrepancy arises from the plate under measurement being a little shorter than the plate from which the settings in Table I were obtained. When the differences from the standard table are plotted against the wave lengths (figure 2) a fairly smooth curve is obtained and from this curve we can read off corrections to be applied to any observed setting to

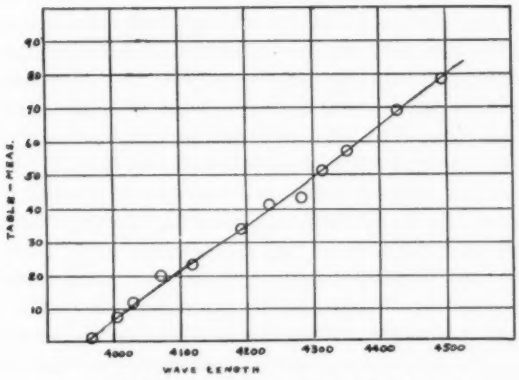


Fig. 2.—Corrections to be applied to observed settings in Radial Velocity measurement.

make it agree with the tabular value in Table I. Corrections read off in this way for the stellar lines are shown in the right hand numbers of column five. These corrections added to the tabular values in Table I give the numbers in the sixth column. These are the readings that would have been obtained for all the stellar lines had the comparison lines agreed with Table I. Comparing the readings in the sixth column with the stellar wave-length settings in Table I, we find that in the plate under measurement the star lines are displaced to the red end of the spectrum by the amounts shown in column seven. These displacements give us at once, by multiplication by the numbers in column eight, the velocity of the star as determined for the various lines. The

result of the multiplication is shown in column nine. Owing to errors of measurement and to uncertainties in the wave-lengths, photographic errors, and other causes, the velocities are not consistent. The lowest is 21.7 and the highest 44 km. per second. This range is quite normal for this instrument. The great bulk of the velocities lie around + 30 km. The mean velocity + 31.38 is consequently subject to an unknown error. A mathematical method is available to estimate the uncertainty of such a result. It works out to be about 0.6 km. The velocity + 31.38 represents the velocity of this star relative to the observer at the time the observation was taken. The observer himself is moving, due to the rotation of the earth and the revolution of the earth around the sun and the motion of the sun itself. It is customary to compute the corrections due to the earth's rotation and revolution around the sun and to publish as a final result the relative velocity of the star and our sun. The total of these corrections, the computation of which is beyond the scope of this article, works out to be − 20.70 km. per sec. Applying this correction to the observed velocity on the plate, we find as a final result for the plate an indicated velocity for the star of + 9.9 km. per sec.

We are not satisfied merely to take one plate of a star and publish the velocity of the star as given by that plate. There is some danger of misidentifying the star, and to make certain our results are not affected by an error of identification and to ascertain that the velocity of the star is constant, we usually take a number of plates. In Table III below are listed all the plates taken of this particular star.

TABLE III.

Plate	Date	Julian Day	Velocity	P.E.	Lines
8154	1942, Aug. 25	2430596.797	+10.0	0.7	23
8448	Nov. 15	0680.560	+ 9.5	1.2	16
9402	1943, Oct. 4	1001.743	+ 8.3	0.5	23
9450	Oct. 9	1006.706	+10.3	0.5	19
9617	Nov. 14	1042.619	+ 9.9	0.6	21

Mean for the five plates is + 9.6 km. ± 0.2 km. per sec.

The agreement of the various plates for this star is somewhat better than we usually expect for plates taken with a one-prism instrument. It is not unusual to find a range of 4 or even 6 km.

per second among a series of four or five plates without being able to say that the velocity is variable. Even for stars in which the lines are sharp and well-defined unless the dispersion of the velocities is over 12 km., we would hesitate to affirm that the velocity is variable. In the case of poor-line stars or where the lines are fewer in number the errors are greater and indeed some of the stars have such poorly defined lines that it is impossible to measure their positions or to obtain a positive result. When the lines are well-defined the accuracy of the results may be increased by using a spectrograph containing two or three prisms, thus making the spectrum longer. Such increase in accuracy is obtained at the expense of speed. A three-prism instrument requires fully five times the exposure of a one-prism instrument to record the spectrum with equal density. For most programmes, the accuracy obtained with a one-prism instrument is sufficiently good.

What has been said above about the accuracy of the results obtained applies only to their consistency among themselves. It is important to test out the correctness of the Doppler principle by measuring the velocities of sources whose motions are known by other means. Probably the best of these are the planets and of these Mars and Venus are the most suitable. The distances and motions of the planets in the solar system are known with great accuracy and consequently their velocity relative to the observer can be computed at any time.

In the table below are shown the results of nine measures made by W. W. Campbell with a three-prism instrument, of the planets Mars and Venus.

TABLE IV.

Date	Object	Meas. Vel.	Comp. Vel.	Difference
1896, Sept. 15	Mars	− 9.05	− 8.55	−.50
Oct. 3	"	− 8.25	− 8.22	−.03
1897, Jan. 14	"	+14.40	+14.53	−.13
July 22	Venus	+13.10	+13.06	+.04
July 22	"	+13.99	+13.06	+.93
Aug. 26	"	+11.52	+11.51	+.01
Aug. 26	"	+11.66	+11.51	+.15
1898, June 8	"	− 9.66	− 9.14	−.52
June 8	"	− 9.61	− 9.14	−.47

The correctness of Doppler's principle is established. It is however by no means true that the reverse proposition holds that when the lines are displaced from their normal positions a radial velocity is the cause. The lines may be displaced by a multitude of causes both mechanical and physical. In attempting to determine radial velocities, we try to eliminate all other known causes for the shifting of the lines, and the rest we ascribe to velocity in accord with Doppler's principle.

Growth of Radial Velocity Research

In the above pages, we have outlined in some detail the methods by which the radial velocities of the stars are obtained by the means of slit spectrographs. Up to the present time, such methods are responsible for practically all our knowledge of radial velocities. Spectrographs at various observatories differ in detail in regard to the extent to which the spectra are dispersed, either by more prisms or by longer or shorter camera lengths being used. Although the possibility of determining radial velocities was initiated by Fizeau in 1848 with the detailed enumeration of Doppler's principle, the practical feasibility was not demonstrated till 1891 with the publication of the velocity of fifty-one stars determined at the Potsdam Observatory which was followed by the epoch-making work of Campbell at the Lick Observatory beginning in the year 1895. We can say that work has been going on for about fifty years only. In the years 1911-1913, Campbell published the first really extensive lists of velocities, the result of over fifteen years' work with a three-prism instrument. The results were given for nearly 1,500 stars including all these of visual magnitude brighter than 5.0 visual magnitude. Only those observatories equipped with large telescopes were able to enter this field; but, besides the Lick Observatory, the Mount Wilson, Yerkes, Victoria, Allegheny, Bonn, Simeis, David Dunlap and other observatories entered the field. In 1932 the Lick Observatory published a very complete summary of all radial velocities published or known to be available though not published up to that time. This catalogue contains 6,739 entries.

Since then, some other extensive lists have been published by the Mount Wilson, Victoria and David Dunlap observatories so

that at present there are available the results for over 9,000 objects, including practically all the stars brighter than visual magnitude 6.0.

The observations of the stars in the southern hemisphere have always lagged behind observations in the northern hemisphere, but with the close of the war, the completion of the Radcliffe Observatory at Pretoria, and the new observatory at Bosque Allegre in Argentina, both of which plan to do extensive radial velocity work, the deficiency will be partly made up.

Objective Prism Spectra

The above description of the determination of the radial velocities applies to the methods adopted with slit spectrographs. Up to the present, practically all useful results have been obtained with such equipment. Over fifty years ago, at the time Scheiner and Campbell were perfecting the slit spectrograph and the photographic method, Pickering at Harvard suggested the use of the objective prism as a method of obtaining radial velocities on a wholesale scale. In the method, a large prism of small angle is placed over the objective of a refracting telescope and immediately in front of the plate is placed an absorption cell of neodymium chloride. The spectra of all the brighter stars in the field of view of the telescope appear on the plate and superimposed on each is the absorption spectrum of neodymium consisting of a single line at λ 4272.8, which serves as a reference for zero velocity. The Harvard Observatory has attempted to apply this method many times and has published over thirty papers, which embody the efforts of various workers to bring the method into useful production. In the latest attempt by Bok and McCuskey, the probable error of a single determination has been reduced to the order of 10 km. per sec. This large probable error, though actually small, considering the difficulties of the method, renders the results of little use when studying variations in the velocity of any particular star but does not render the results useless for statistical purposes. When studying average velocities of groups of stars, we are taking means of velocities, which, if known with great precision, would have a scatter of possibly 50 km. per sec. The average value obtained for such a group will be about as good,

whether the individual velocities have been obtained with a probable error of 10 km. per sec. or a probable error 1 km. per sec., provided we can be certain that the velocities obtained with the larger probable error are not accompanied by systematic errors as well. The objective prism method gives good promise of yielding results of great value for the faint stars.

Contribution to Our Knowledge of the Universe

During the past fifty years, in which the radial velocities of the various objects in the sky have been accumulating, the results have contributed very greatly to our knowledge of the universe. First, we have the determination of the solar motion. At the time this was made, it seemed to represent our true motion in the universe of stars. The second great advance, resting largely on radial velocity results, was that the above motion applied only to a very local vicinity of stars and that this cluster was in slow revolution (period about 200 million years) around a distant centre with a speed of over 350 km. per sec. A third remarkable result from the measures of the positions of spectrum lines is that extremely distant objects, the spiral nebulae, show progressively greater and greater red shifts the farther they are away. Whether this red shift represents a true velocity or not, has not been determined, but in the meantime, it has served the very useful purpose of determining the distance of many of the nebulae. Besides these results, which concern the universe of stars as a whole, radial velocities have helped very greatly in the study of the evolution of a star, the results from the study of spectroscopic binaries and variable stars being particularly informative. In a recent summary of our knowledge of the Milky Way, Bok remarks that without adequate stellar radial velocities, galactic research would be in a sorry state.

David Dunlap Observatory,
Richmond Hill, Ontario,
December, 1945.

WINTER EXERCISE MUSK OX

By PETER M. MILLMAN*

IN the middle of February this year a group of some fifty trained personnel will set out from Churchill across the ice on an Arctic trek that will cover approximately 3,000 miles before terminating in Edmonton during the first week in May. This is the combined Canadian Army-Air Force winter exercise, code name "Musk Ox", planned for the purpose of studying conditions encountered in our far north in mid-winter. Every opportunity for research which this exercise offers is being utilized in an effort to learn more about the vast, little explored area in the north of Canada.

The approximate route of the party has been indicated in the accompanying figure. The most northerly point reached will be Denmark Bay on Victoria Island, at a latitude just over 70 degrees North. The ground party will move in twelve large, full-tracked snowmobiles of a type known as "Penguins." They will be supplied from the air by specially equipped Dakota and Norseman aircraft operating out of air bases at Churchill and Yellowknife.

Research problems being studied on this exercise have been listed under 24 separate headings. They include, among other subjects, a complete study from both the air and ground of the meteorological conditions, the earth's magnetic field, radio and radar performance, methods of navigation in the north, and the aurora.

On the recent polar flights undertaken by the British aircraft "The Aries" there was a fairly definite indication that the magnetic lines of force, as measured 10,000 to 20,000 feet above the earth's surface in the region of the magnetic north pole, do not agree very closely with those determined by accurate ground observations. The Dominion Observatory is sending two magnetic experts on Exercise Musk Ox to carry out ground magnetic observations. One of these observers will remain at Baker Lake throughout the period of the exercise, the other will travel with the ground party. To obtain air values of the earth's magnetic field for comparison with the ground measures all Dakota supply aircraft have been

*Squadron Leader, R.C.A.F., Division of Research and Development, Air Force Headquarters, Ottawa.

equipped with three-axis magnetometers. These instruments measure the strength of the earth's field in three perpendicular directions and will be read at frequent intervals during the flights. While the accuracy that can be obtained in the air does not approach that of the ground values, it is hoped that enough data will be procured to shed further light on the apparent magnetic anomalies in the Canadian North.

It is a well-known fact that auroral activity can be correlated with magnetic disturbances and other related phenomena. It is particularly desirable to have as complete observations of the aurora as possible during the period of Musk Ox. Regular auroral observations will be made at the meteorological ground stations associated with the exercise and by observers with the moving party. Auroral records will also be kept, where possible, in the air. It would add greatly to the value of the program if members of the Society could make additional observations of the aurora where possible. These should be mailed to the Division of Research and Development, Air Force Headquarters, Ottawa, and marked "Musk Ox-Auroral Observations."

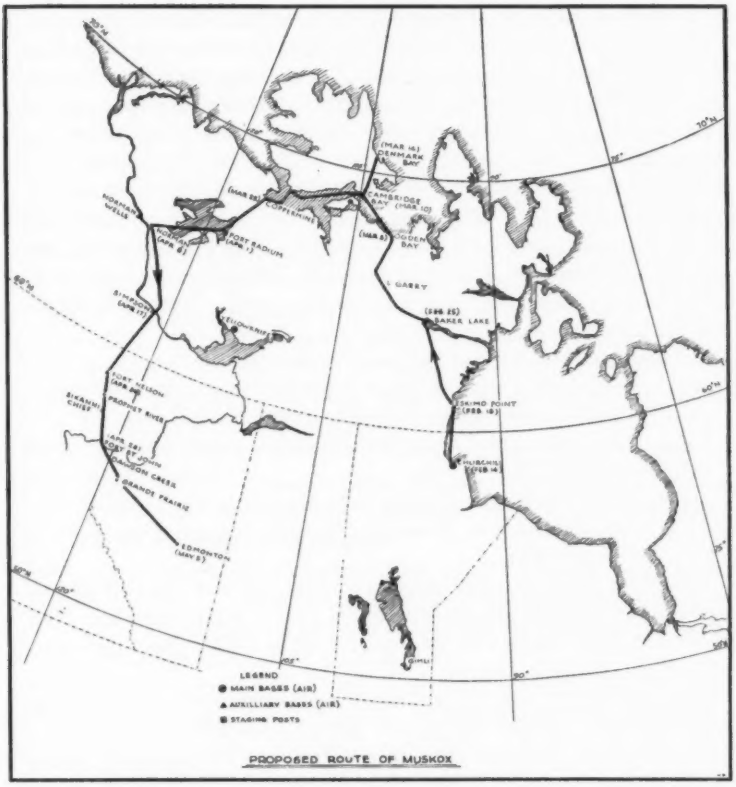
The form used for reporting these observations should be drawn up as indicated below:—

EXERCISE MUSK OX — AURORAL OBSERVATIONS

Night of..... Location.....

G M T		Auroral		Sky	
h	m	Form	Intensity	Condition	Remarks

The following instructions have been issued to those on the Exercise and should also be followed by any of the R.A.S.C. members making reports:—



PROPOSED ROUTE OF MUSKOX

Instructions for Auroral Observations

The night on which the observations are made should always be recorded as a double date (*e.g.*, Feb. 11/12). The location of the observer is to be given in latitude and longitude. Wherever possible, routine records should be made at approximate hourly intervals and the G M T filled in to the nearest five minutes in the first two columns of the form. Any unusual auroral activity is worthy of more frequent recording and additional details can be filled in on a blank sheet of paper.

The type of auroral form visible is to be recorded in column three, using the standard abbreviations given in the "Photographic Atlas of Auroral Forms" published by the International Geodetic and Geophysical Union in Oslo, 1930. These abbreviations and their descriptions as taken from the Atlas are given below for convenience. The majority of the plates from the Atlas were reproduced on a slightly smaller scale in the *Journal* for January, 1929, but the abbreviations accompanying them are not standard and should not be used. *It is just as important to record periods when no aurora is visible as to make the positive observation of an auroral form.* Use the abbreviation "N" when no auroral illumination is present.

A value of the auroral intensity on a scale of I to IV is to be given in column four of the form. Intensity values are as follows:

I. Faint aurora, about as bright as the Milky Way.

II. Medium aurora, about as bright as a thin moonlit cirrus cloud.

III. Bright aurora, as bright as a moonlit cumulus cloud.

IV. Brilliant aurora, gives enough light to approximate direct moonlight.

Sky condition is noted in column five, and the observer should indicate whether it is partially cloudy, hazy, bright moonlight, etc. Care must be taken not to mistake high cloud, illuminated by moonlight, for true aurora.

Column six should contain any amplifying notes concerning the observations. Where additional space is required, use another sheet of paper. Of particular interest to note are: unusual colours of the aurora, types of pulsations or movement, the location among the stars of the centre point or convergence of a corona, and in particular the time, to the nearest minute if possible, when one type of auroral display changes into another. If an isolated form remains for some time in the sky, its position should be noted either with respect to the stars or in altitude and azimuth.

Description of Auroral Forms

1. FORMS WITHOUT RAY-STRUCTURE

HA *Homogeneous Arc.*—The arc is usually diffuse above and sharply defined below. It may be near the horizon or quite

isolated high in the sky. Sometimes several parallel arcs occur and may be connected at one end by a sharp curve. The colour is usually greenish yellow or nearly white. The arc often gradually climbs up the sky and may later have a very luminous irregular lower border and soon after break into rays (type RA). The arc is usually set almost at right angles to the magnetic meridian. Often only parts of arcs are visible.

HB *Homogeneous Band.*—This band has a more irregular form than the homogeneous arc. It may vary from narrow to very wide. The lower border is often irregular and sharply defined. It may sometimes consist of a segment of approximately semi-circular shape which may move across the sky in the direction of the usual arcs HA. The band may have folds and resemble a large curtain. This usually changes into bands with ray structure (type RB). The colour is generally bluish white.

PA *Pulsating Arc.*—Arcs, or parts of them, may flash up and disappear rhythmically with a period of 10 to 30 seconds. The colour is usually bluish green.

DS *Diffuse Surface.*—A diffuse veil or glow, often over large parts of the sky. It may resemble clouds and often appears after rays or curtains. The colour may range from violet white to an intense red.

PS *Pulsating Surface.*—A diffuse patch or surface which appears and disappears rhythmically. Near the zenith the boundary may be sharper. Often appears with, or as part of, a flaming aurora (type F).

G *Glow.*—A faint glow near the horizon resembling the dawn, usually white or greenish colour but sometimes red. This is often the upper part of an arc whose lower border is below the horizon.

2. FORMS WITH RAY-STRUCTURE

RA *Rayed Arc.*—An arc with ray-structure. A quiet homogeneous arc often becomes very luminous and then breaks into rays. The rays may be short or long and may vary in brightness along their length.

RB *Rayed Band.*—A band with ray-structure. Resembles type HB but composed of rays. The rays may be close together or scattered along the band. Several parallel bands may appear. Near the magnetic zenith the bands may form a corona.

D *Draperies.*—When bundles of rays become long the band often assumes the form of a curtain or drapery. The lower border is often more luminous. Near the zenith they may have a fanlike form like a partial corona.

R *Rays.*—Rays resemble searchlight beams in a dusty atmosphere. The rays may appear isolated or in great bundles. They are usually greenish yellow but may be red. Rays often appear with other auroral forms.

C *Corona.*—When rays approach the magnetic zenith they seem to converge to a point because of perspective. The corona may be formed by long or short rays, by bands, or by draperies.

3. FLAMING AURORA

F *Flaming Aurora.*—A quick moving form consisting of waves of luminosity moving toward the magnetic zenith, or of dark waves which cause parts of arcs, bands or patches to appear and disappear rhythmically. Often appears after strong displays of rays and curtains and is frequently followed by the formation of a corona.

NOTE ON LIGHT INTENSITY DURING LUNAR ECLIPSE

By F. L. Tabrah and R. M. Tabrah

IN planning an observing program for the recent lunar eclipse, it was felt it might be of interest to study quantitatively the changes in illumination of the moon's visible disc, plotting a curve of the observed intensity of the reflected light.

Because it was impossible to secure a satisfactory photoelectric means of measurement, a simple but effective apparatus was arranged as follows.

At the focus of a 2-inch achromatic objective, a small frame was arranged to hold a pack of translucent paper discs, allowing for quick change of the number of discs in the pack. When viewed from behind, as in a Graflex camera, it was found that 52 such discs would permit a visible image of the full moon to be seen, whereas 53 discs would not. Thus, 52 discs were taken to represent 100 per cent illumination, and each disc cut off slightly less than 1.9 per cent of the light passed into the pack. As illumination changed during

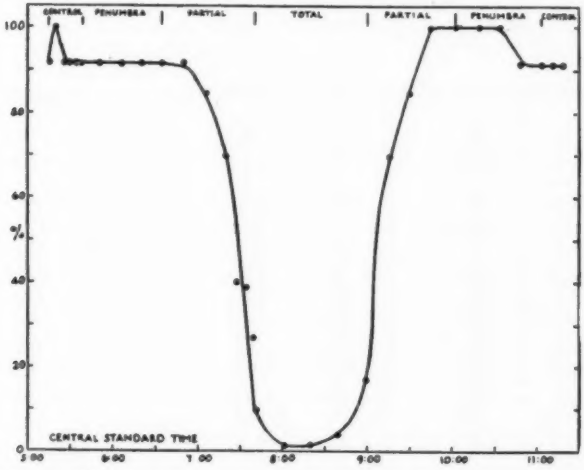


Fig 1.—Light Intensity during Lunar Eclipse, December 18, 1945.

the eclipse, discs were removed or added as necessary to keep the image at its critical intensity, that at which it would disappear with the addition of a single disc. With each disc representing 1.9 per cent of full brilliance, it was fairly simple—by counting discs—to plot the accompanying intensity curve in terms of per cent illumination and time.

Control period preceding 5:38.5 CST showed intensity drop to about 92 per cent because of slight haze that appeared soon after moonrise.

It was interesting to us that no visible reduction in intensity occurred during passage through the penumbra, or until fairly well immersed in the umbra. As can be seen by the curve, the illumination dropped precipitously and stayed at about 2 per cent throughout most of totality, rising quickly to its highest observed value which on previous nights was considered 100 per cent illumination. The terminal drop was again due to slight haze which produced a faint halo. No attempt was made to determine change in the intensities of separate colours.

Determinations were made from an open platform with the temperature—to our great discomfort—fifteen below zero, but we enjoyed the eclipse thoroughly as our brief observations were accomplished as planned.

OBSERVATION TIMES AND PERCENTAGE ILLUMINATION

Time C.S.T.	Ill. Per cent	Time C.S.T.	Ill. Per cent	Time C.S.T.	Ill. Per cent
5:15	92.1	7:07	84.5	9:30	84.5
20	100.0	22	69.2	45	100.0
25	92.1	29	40.0	10:03	100.0
30	92.1	34.5	38.5	18	100.0
35	92.1	39.5	26.9	33	100.0
38.5	92.1	40.5	9.6	48	92.1
53	92.1	8:00.5	1.9	11:02	92.1
6:08	92.1	20.5	1.9	12	92.1
23	92.1	40.5	3.8	17	92.1
37.5	92.1	9:00	15.2		
52	92.1	15	69.2		

Tomah, Wisconsin

JUPITER AND SATELLITES I, II, III, AND IV DURING 1946

By Charles E. Apgar

THE following table, in continuation of work published previous years in The Journal, gives the periods during 1946, when Jupiter's satellites will be either all East or all West of Jupiter. The times given are for the 75th meridian (Eastern Standard Time).

1946	All	Begins at	Duration
Jan. 8	East	06h 06m	19h 01m
17	West	23 39	14 48
22	East	09 52	19 02
Feb. 1	West	03 24	16 14
6	East	07 00	01 38
12	East	16 25	18 03
15	West	07 04	17 46
22	West	08 52	14 25
26	East	21 15	16 49
Mar. 8	West	12 27	18 15
13	East	01 57	15 40
22	West	15 57	18 32
Apr. 3	East	08 48	14 03
4	East	22 08	02 21
5	West	19 26	18 50
12	West	21 10	18 59
17	East	13 35	12 43
27	West	00 39	18 57
May 1	East	18 47	11 00
3	East	05 34	03 52
11	West	05 16	17 50
23	East	02 34	08 32
24	East	11 17	05 04
25	West	12 14	14 26
28	West	20 38	03 01
June 1	West	15 48	12 40
12	West	00 17	06 35
15	West	23 11	08 57

	19	West	02	08	06 07
	20	East	12	57	05 29
	21	East	18	56	07 08
	27	East	15	32	01 22
	30	West	06	51	05 02
July	3	West	05	54	12 19
	11	East	20	43	03 24
	13	East	00	41	09 04
	17	West	09	44	16 27
	27	East	04	32	10 31
	31	West	13	36	18 57
Aug.	7	West	15	34	18 58
	9	East	07	02	00 51
	10	East	08	22	12 05
	16	East	09	36	00 15
	21	West	19	30	18 59
	31	East	14	07	14 38
Sept.	4	West	23	29	19 01
Nov.	16	West	14	04	02 21
	17	East	16	07	14 27
	24	East	13	26	18 59
	29	West	06	49	11 28
	30	West	18	05	03 27
Dec.	8	East	19	41	16 44
	12	East	06	26	01 19
	13	West	12	25	09 39
	14	West	22	04	04 36
	20	West	15	12	08 46
	23	East	04	25	11 59
	26	East	10	25	06 05

The following gives the eight periods during 1946 when Jupiter apparently will be attended by only one satellite.

The times given are for the 75th meridian (Eastern Standard Time).

Configuration as observed through an inverting telescope.

1946	Configuration	Begins at	Ends at	Duration
Jan. 24	d*d-0-4	$01^h\ 01^m$	$01^h\ 20^m$	$00^h\ 19^m$
27	d**-0-4	14 16	15 11	00 55
31	4-0-*dd	03 31	05 09	01 38

Feb. 3.....	4-0-*d*	17	00	18	58	01	58
7.....	dd*-0-4	07	00	08	01	01	01
10.....	*d*-0-4	20	45	20	55	00	10
17.....	4-0-**d	21	36	22	20	00	44
24.....	d**-0-4	23	58 (25)	00	31	00	33

Configurations—

0 represents the disc of the planet.

* signifies the satellite is occulted or eclipsed.

d signifies the satellite is on the disc.

549 Carleton Road,
Westfield, N.J.
June 28, 1945.

THE 1942-3 APPARITION OF JUPITER

By WALTER H. HAAS

(With Plate III)

INTRODUCTION

WHEN Jupiter was at opposition on January 11, 1943, its declination of $+22°$ made it well placed for northern observers. This paper will report observations carried on by a small group of chiefly American amateurs from July 28, 1942, to July 2, 1943. The dates above and all other dates in this paper are by Universal Time. The coöperating observers are listed below. Wartime conditions greatly reduced observing. Most of the data used for this paper were obtained by Haas with the 18-inch telescope, and very little work was done from early October to early January.

Name	Telescope	Station	Remarks
W. H. Haas	6-in. refl.	New Waterford, Ohio	
W. H. Haas	18-in. refr.	Upper Darby, Pa.	Flower Observatory
H. M. Johnson	18-in. refr.	Upper Darby, Pa.	Observed with Haas
H. M. Johnson	4-in. refr.	Rochester, N.Y.	C. F. Gramm's Telescope
R. G. Johnson	8-in. refr.	Des Moines, Iowa	Drake Observatory
F. R. Vaughn	9-in. refl.	Plainfield, N.J.	
F. R. Vaughn	18-in. refr.	Upper Darby, Pa.	Observed with Haas
E. K. White	9-in. refl.	Chapman Camp, B.C., Canada	
L. J. Wilson	12-in. refl.	Nashville, Tenn.	Used for photography

Such subjects as the proper methods of observing Jupiter, the nomenclature of the belts and zones (note Plate III), and the two systems of longitude used have been treated elsewhere.[1,2] This paper will use these abbreviations: *S* for south, *N* for north, λ for Jovian longitude, *C.M.* for central meridian of longitude, *p* for preceding (direction of decreasing longitude), *f* for following (direction of increasing longitude), *B* for belt or band, *Z* for zone, *R* for region, *E* for equatorial, *Tr* for tropical, *T* or *Te* for temperate, and *P* for polar.

Two drawings of the whole disc on Plate III, though lacking in detail, may be regarded as typifying the general appearance of the planet in 1942-3.

The Belts and Their Intensities

Data on belt-intensities in 1942-3 fall under three heads:

1. Haas made 58 sets of estimates of the *intensities* of the belts on an arbitrary numerical scale between August 19 and June 4.

2. White and H. Johnson sometimes estimated the relative *conspicuousnesses* of the belts, using conspicuousness to mean an integrated effect of intensity and width.

3. Most of the observers, especially Haas, recorded notes about the strength and appearance of the belts; and some additional information is given by drawings and by Wilson's photographs.

The *NEB* was at all times much the most conspicuous belt. Its *average* intensity was comparable to that of the darkest other belts, and its much greater width made it easily dominant. In August - September this belt was darker than during the 1941-2 apparition, but in January - May it was about the same intensity as in 1941-2. The darkness was otherwise apparently fairly stable. The structure of the *NEB* was very complex, some areas in it being far darker than others. In August and September Vaughn and Haas found the *NEB* split into two components, which were equally wide and wider than the gap between them. On September 11 the belt was single p λ_1 190° and λ_2 30° and double f that position. Duplication was last recorded on September 24.

The *STB* was probably the second most conspicuous belt; at least it was usually much darker than the SEB_n, its only rival for second. Its darkness, usually as great as that of any other belt, was fairly constant throughout the apparition; and it seldom differed greatly in intensity in different longitudes, though it was especially light near λ_2 20° in April and May. The *STB* was lighter than during the latter half of 1941-2 and was about as intense as during the first half of that apparition.[3] Haas on September 6 in good seeing estimated the width of this belt with CM_2 351° to be considerably less than 0″.9. Later, however, several wider or doubled sections were observed.

The SEB_n, which lay about midway between the *NEB* and the *STB*, was probably usually the third most conspicuous belt, thus ranking higher than in 1941-2.[3] At the start of the 1942-3 apparition the SEB_n was about the same intensity as in the spring of 1942, and it grew gradually somewhat darker as the apparition advanced.

There is little evidence of rapid changes in intensity. In August Vaughn divided the SEB_n into two components regularly, as Haas did with his six-inch on September 6 at CM_1 120°. The equally dark and wide components were wider than the separating gap and were less easy to split than the *NEB* components then visible. In the 18-inch, Haas found the SEB_n doubled on September 15 at CM_1 85° but single on September 17 at CM_1 74° with an equally good view. H. Johnson probably saw two components on October 12 at CM_1 9°. Duplicity was disappearing, though, and was last seen *f* λ_1 25° on November 9.

The *NTB* ranked fourth in conspicuousness, lower than in 1941-2.[3] It was usually at least as dark as any other belt; but it was extremely narrow, White considering it possibly half as wide as the *STB*. The intensity of the *NTB* was usually the same as in 1941-2; but in December and January it was extremely dark, being then easily the darkest of all the belts. This belt showed rapid variations in intensity and considerable differences in intensity at different longitudes. Examples follow: Near λ_2 190° it lightened from January 23 to February 9 but was darker again on February 17 and 19. The belt was lighter *f* λ_2 210° on September 17 and 24. Sometimes the transition was gradual so that the belt grew progressively lighter or darker with increasing longitude across the disc.

White ranked the SEB_s fifth in conspicuousness, and it probably averaged more conspicuous than in 1941-2.[3] It was nevertheless often both thin and faint and frequently was not visible with the smaller telescopes used by the group. During most of 1942-3 this belt was at least approximately the same intensity as in 1941-2; but in March and April it grew definitely darker, and by early June the SEB_s was perhaps more conspicuous than the SEB_n. Rapid changes in intensity were apparently rare, but on March 2 the SEB_s was much less dark *f* λ_2 70° than on March 14 or 24. The effects of the Red Spot Hollow and the *STrZ* Disturbance on the belt will be reported below.

The *NNTB* perhaps ranked sixth in conspicuousness. Narrow and often faint as well, it was occasionally invisible even with the Flower 18-inch. This belt was about as intense and as conspicuous as in 1941-2.[3] It probably grew gradually darker during 1942-3 but still averaged rather faint when the apparition ended. Some

sections of the *NNTB* were much darker than others. For example, this belt was lighter *f* about λ_2 120° from late December to late March, perhaps throughout the apparition, and was darker *f* λ_2 390° in February. It was twice seen to be much darker *f* a dark spot in it. Inadequate evidence suggests that rapid variations in intensity were exceptional here.

The *SSTB* was about as conspicuous as the *NNTB* if frequency of visibility with the 18-inch may be used for judging conspicuousness and was also about as intense as the *NNTB*. The other telescopes seldom showed the *SSTB*, which was relatively less conspicuous than in 1941-2,[3] though about the same intensity. Near λ_2 205° this belt was darker on February 2 than on January 23 or February 9. The belt was frequently seen to be of different intensities in different longitudes, and one of the darker sections is of special interest. Its *p* end lay near λ_2 180° on February 9 and had drifted to near λ_2 140° by March 24. This darker section grew darker from February 9 to March 15, but had lightened by March 24. The latitude of the *SSTB* varied, and near λ_2 200° on February 2 and λ_2 165° on February 19 it was seen to deflect northward so as to lie closer to the *STB f* those positions.

The *NNNTB* ranked eighth in conspicuousness or at least in frequency of visibility with the 18-inch telescope, which showed it about half the time. It was faint and probably grew less conspicuous during 1942-3. On the average, the *NNNTB* was about as intense and as conspicuous as in 1941-2.[3] Near λ_2 240° this belt was darker on September 5 than on September 15. It differed in intensity in different longitudes and was *very* vague or absent between λ_2 10° and λ_2 100° throughout the apparition.

The *SSSTB* ranked ninth in frequency of visibility, being recorded only 14 times and only with the 18-inch. The intensity and the width of its visible portions were comparable to those of the *SSTB*. The *SSSTB* was unquestionably stronger during the first half of 1942-3 than in 1941-2,[3] but it grew more delicate as the later apparition advanced and was last certainly seen on February 19. This belt was unusually dark near λ_2 20° in early October.

Recorded only seven times, the *EB* ranked tenth and was even so more conspicuous than in 1941-2.[3] The intensity of the few visible portions ranged from extreme faintness to the darkness of

the *NTB* and the *STB*. The *EB* was probably unusually strong near λ_1 90° throughout 1942-3, but it is also possible that the visible portions remained visible only briefly. On January 10 at CM_1 120° the *EB* lay south of the middle of the *EZ*; on April 24 at CM_1 97° it occupied its 1939 position near the north edge of the SEB_n.[2]

An *STeZB*, an arbitrary designation for a belt between the *STB* and the *SSTB*, ranked eleventh, being recorded only four times. The dates of observation are January 23, February 19, and March 9. This belt was usually not particularly faint in its few visible sections. On February 19 the *f* end of a visible section was seen to merge with dark matter in the *STeZ* near λ_2 160°, this *f* end having probably lain near λ_2 190° on January 23.

Two belts occasionally recorded in 1941-2, the *NNNNTB* and the *SSSSTB*,[3] were never observed in 1942-3.

Other General Appearances

In the spring of 1943 Haas thought that both polar shadings were light, and photographs by Wilson on February 28 and March 15 apparently confirm their faintness. The *SPR* was perhaps somewhat larger and darker than the *NPR*.

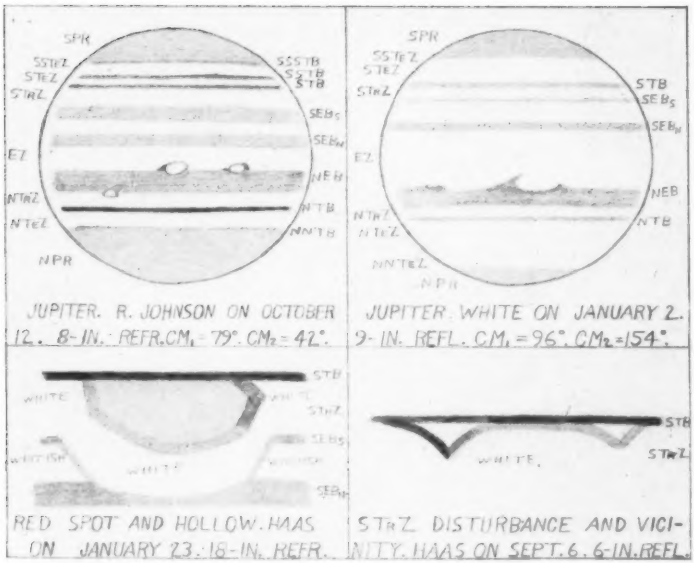
The *NPR* may have been regularly bounded by the *NNNTB*. At least such was true in late August and early September; Haas then regularly saw the wide combined *NTeZ-NNTeZ* observed in the spring of 1942.[3] Subsequent notes upon either zone are lacking.

In September the *NTrZ* was narrow, probably averaging somewhat less wide than the *NEB*. Drawings by R. Johnson and White indicate that in October and January it was much less wide than that belt. *Perhaps* it was wider in March and April. The only specific reference to the brightness of the *NTrZ* is untypical: H. Johnson on June 9 at CM_2 117° called it the whitest of the zones.

In late August the *EZ* was the whitest of the zones in all longitudes, as it had been in March-April, 1942.[3] Scanty evidence suggests a progressive dimming during the 1942-3 apparition. The space between the *SEB* components was wide, the SEB_s being once called closer to the *STB* than to the SEB_n. This space usually looked dull or dusky to Haas in February - June.

The *STrZ* was never wide, but near April 1 it began to impress

PLATE III



Drawings of Jupiter, 1942-1943, showing disturbance STrZ.

Haas as narrower than it had been for some years. On May 5 and 6 he thought it *about* three-fourths as wide as the *NEB*. This zone was called a rather dull white, except on April 18 when it tied with the *EZ* for being the brightest zone.

The *STeZ* varied greatly in width. On and near September 6 and 17 it was as narrow as the *STB*, probably at all longitudes. By October 2 and 8 it had widened to several times the breadth of that belt. From late December to mid-May it showed large fluctuations in width and was much broader in some longitudes than in others. Some portions of the *STeZ* were fairly bright.

The shaded *SPR* was perhaps usually bounded by the *SSTB* during the latter half of the apparition and perhaps sometimes by the *SSSTB* when that belt existed. An *SSTeZ* was noted near λ_2 40° on September 11 and October 12, and it is *possible* that the wide combined *SSTeZ-SSSTeZ* observed in the spring of 1942 existed early in 1942-3.

Colours

Available data on colours in 1942-3 consist of 50 estimates by Haas with a six-inch reflector on eight dates in early September and mid-April and 26 estimates by Vaughn with a nine-inch reflector on three dates in August. Haas used Eastman Kodak Company Wratten Filters 25 (red), 58 (green), and 47 (blue) as an aid in distinguishing colours.

The shaded *NPR* showed bluish or brownish tints to Vaughn in August, looked sensibly gray to Haas in September, and usually showed bluish tinges to Haas in April. Any changes in colour are uncertain.

The *NTB* looked bluish to Vaughn on August 31 and regularly showed copper-red to Haas.

The *NTrZ* appeared to be a dull yellow or white to Vaughn in August and looked white to Haas in September. Was it less yellow than in September - November, 1941?[3]

Vaughn usually thought the *NEB* reddish-brown, and Haas recorded an apparently variable red tone perhaps richer in April than in September.

The *EZ* looked white to both observers, being perhaps whiter than during the first half of the 1941-2 apparition.[3]

Rather faint to be judged for colour, the SEB_n exhibited bluish

tinges to Vaughn and looked copper-red to Haas. Haas' notes would make the belt redder than in August, 1941,[3] perhaps because darker.

The *STrZ* appeared yellowish-white to Vaughn on August 18, so dull as to be almost gray to Vaughn on August 31, and white to Haas on April 18.

The *STB* showed a dark copper-red or blood-red tone to Haas and brownish or bluish tints to Vaughn. The former observer's results suggest that this belt was more red than in August, 1941.[3]

The shaded *SPR* to Vaughn showed a brownness which may have grown less conspicuous from August 6 to August 31 and to Haas was sensibly gray in September and was usually tinged by blue in April. Any changes are uncertain. There was little difference in hue between the two polar shadings.

Except where specifically noted otherwise above, the pattern of colours was much as in 1941-2; and Haas on April 4 commented on the resemblance.

Red Spot and Hollow

Early in the apparition, and indeed as late as December 22, the Spot showed the same delicate character as late in 1941-2;[3] and Haas could only sometimes discern the *p* and *f* ends as dark marks at the north edge of the *STB*. By January 10 the Spot had strikingly revived and was a conspicuous semi-oval adjacent to the *STB* (Plate I); and on January 23 Haas noted that it was stronger than it had been for some years. It was much darker at its *f* edge than elsewhere, as in 1941-2;[3] and its interior was only slightly duller than the *STrZ*. During 1942-3 no lighter space was ever seen between the Spot and the *STB*, nor was the belt ever indented beside the Spot. On February 9 the famous feature was already fading, and by March 2 it was so faint that only its *p* and *f* ends were easily seen. On March 15 Haas could distinguish only the *f* edge in fairly good seeing, though Wilson has written that *the original* of his photograph on that date shows the Spot. A transit of the *f* end of a vague Spot was recorded on March 25, but from March 29 to July 1 no part of the mark was ever even suspected.

No sign was ever seen of a Red Spot Hollow in August - October, nor did this portion of Jupiter arouse comment on November 9. The next observation, on December 17, revealed a large white oval

in the *STrZ* forcibly reminiscent of the Hollow in 1938 and 1939.[2] On December 22 the huge oval was gone! While the Red Spot was comparatively conspicuous in January - March, the Hollow was the same rather dull white tone as the *STrZ* and revealed itself only by its effect on the *SEB* components. After the Spot had become invisible, faint dark columns across the *STrZ* developed and marked the ends of the Hollow, the one at the *p* end being first recorded on March 29 and the one at the *f* end on April 6. The Hollow between the columns was still the same intensity as the *STrZ* on April 25; but a poorer view on April 27 showed it brighter than the zone, as was subsequently regularly its aspect. No further changes were noted, the last observation falling on July 1.

The Spot apparently no longer had an effect on the *STB*, as it had had in 1941-2;[3] but the Hollow did affect the *SEB* components. On January 10 the SEB_n was deflected northward by the Hollow, and on January 23 its south edge was depressed (Plate III). On March 15 this edge was no longer visibly depressed. The SEB_s was apparently quite unaffected by the then undiscernible Hollow in September - November, but between December 22 and March 10 this belt was either absent or very faint between λ_2 150° and λ_2 190°. Fairly good seeing on March 15 showed it faintly present across the Hollow. It continued to strengthen there and by April 25 was probably as dark across the Hollow as *p* and *f* that feature. On June 7 the SEB_s was called "fairly strong" at CM_2 155°. The belt was about equally dark *p* and *f* the Hollow in 1942-3, except that on December 22 Haas found it stronger *p* λ_2 150° than he had ever seen it during the 1940-1[4] and 1941-2[3] apparitions. Either the SEB_s or the south edge of the *SEB* was regularly seen depressed by the Hollow from December 17 to March 24, but from March 29 to June 17 no visible deflection could usually be seen. Is it significant that the effects of the Red Spot Hollow on the *SEB* components became less as the Red Spot faded out?

Disturbance in *STrZ*

This object was a rather faded remnant of a feature strikingly conspicuous near the 1941 opposition.[3] The first view after conjunction, on August 25, showed the mark enough like late 1941-2 to be recognized. Better views on August 30, September 6, and

September 11 revealed that the Disturbance now consisted only of a large pointed hump at the north edge of the *STB* (Plate III). Intense at its *p* edge, the hump was otherwise lighter than the belt. A similar if fainter hump *f* the first by about 15 degrees (Plate III) was thought at the time to mark the *f* end of the Disturbance; but subsequent study, particularly of its motion, is adverse to such an interpretation. The Disturbance was subsequently observed on September 23, September 28, October 7, and October 12 and probably grew less conspicuous as time passed, though preserving the same general aspect. The group's work was almost nil for three months subsequent to October 12, but British failure to record the Disturbance after October 5[5] indicates that it was invisible soon after our last observation.

The *STB* near the Disturbance had evidently revived near the 1942 conjunction and was no longer certainly affected by proximity to that object.[3] In September and October the SEB_s was found to be darker *f* the longitude of the *f* end of the Disturbance than in other longitudes and to be very faint or invisible *p* that mark. This resemblance to 1941-2[3] was especially strong on September 11 when the resuming SEB_s was drawn deflecting northward to its normal latitude from a base on the small Disturbance, though on October 7 the belt was shown resuming at its ordinary latitude. These effects apparently vanished when the Disturbance vanished.

Rotation Periods

These were derived in the usual way from visual *CM* transits[1,2]. Our group observed 692 transits, 673 by Haas, not enough for complete coverage of the planet. The drifts presented below were deduced only for marks observed at least three times and followed for at least 15 days. In the tables which follow the first column gives an identifying number to the feature. The second column describes it as dark *D* or white *W* and states whether the *p* or *f* end was watched if the centre was not. The third column gives the dates of the first and last transits. The fourth column states how many transits were observed. The fifth column gives the oppositional longitude, placed in parentheses if the mark was not being followed on January 11. The sixth column states the average change of longitude in 30 days to the nearest whole degree. The seventh column gives the period.

NNTB

No.	Description	Terminal Dates	Number Transits	λ_2 ☍	$\Delta\lambda/30^d$	Period
1[a]	D	Sept. 17 - Oct. 4	3	(76°)	−37°	9h 54m 50s

[a]*If* a somewhat fainter spot seen on December 22 is this mark, the average period is 9h 55m 11s.

The few transits that refer to this belt were of dark spots in it and of terminal ends of darker sections. Perhaps the spots were scarcer after March.

NTeZ and NTB. No drifts can be deduced from very few transits that relate to terminal ends of darker sections of the *NTB* and to dark spots in the *NTeZ.*

S edge NTB. On October 7 and on November 9 Haas observed a dark wisp at this latitude, suggesting that there was a remnant (a revival?) of the 1939-41 activity there.[6]

NT,Z and N edge NEB.

No.	Description	Terminal Dates	Number Transits	λ_2 ☍	$\Delta\lambda/30^d$	Period
1[a]	D	May 17 - June 6	3	(40°)	− 3°	9h 55m 37s
2	Wp.	Mar. 9 - June 6	3	(40)	−10	9 55 27
3	Wf.	Mar. 9 - June 6	4	(49)	−10	9 55 27
4	Dp.	Mar. 2 - June 6	8	(84)	−15	9 55 20
5[b]	Df.	Mar. 2 - May 18	8	(95)	−16	9 55 19
6	W	Mar. 29 - Apr. 29	3	(108)	−18	9 55 16
7	D	Mar. 24 - Apr. 29	4	(131)	−21	9 55 12
8[c]	Wf.	Nov. 9 - Jan. 10	3	(161)	−21	9 55 12
9	Dp.	Mar. 15 - May 7	6	(193)	−10	9 55 27
10	Df.	Mar. 15 - May 7	6	(194)	− 8	9 55 30
11	D	Aug. 30 - Sept. 23	3	(200)	+40	9 56 35
12[a,c]	W	Jan. 23 - Feb. 9	3	(210)	−12	9 55 24
13	D	Mar. 15 - June 29	5	(247)	− 8	9 55 30
14	Dp.	Mar. 6 - Apr. 25	5	(294)	−10	9 55 27
15	Df.	Feb. 8 - May 26	9	(309)	−11	9 55 26

Average..... 9h 55m 29s
Average without No. 11 9 55 24

[a]Sometimes transits of the *p* and *f* ends were averaged to obtain the longitude of the centre.

[b]The drift was perhaps sinuous.

[c]This mark is probably shown in a drawing by R. Johnson on January 28.

During the latter half of the apparition there was a series of alternating dark condensations and bright bays along the edge of the belt. In August and September, but not later, dark projections were frequently recorded there. The *NTrZ* was almost wholly void of detail.

A rift in the *NEB* near λ_2 10° on September 11 and apparently moving in System II had grown much wider by September 23.

S edge NEB and N part EZ.

No.	Description	Terminal Dates	Number Transits	λ_1 ☍	$\Delta\lambda/30^d$	Period
1[a]	D	Mar. 24 - Apr. 25	5	(1°)	− 7°	9h 50m 21s
2[b]	D	Aug. 25 - Sept. 17	3	(52)	+ 5	9 50 37
3[c]	D	Aug. 30 - Feb. 19	7	72	− 8	9 50 19
4[d]	D	Mar. 25 - June 15	4	(81)	−12	9 50 14
5	Wf.	May 28 - June 29	4	(93)	− 6	9 50 22
6	D	Nov. 9 - Apr. 5	4	96	− 4	9 50 25
7	D	May 28 - June 29	4	(107)	− 7	9 50 21
8	W	Sept. 6 - Oct. 8	3	(119)	− 2	9 50 27
9[a]	D	Feb. 17 - May 19	8	(144)	− 8	9 50 19
10[e]	D	Feb. 8 - May 3	7	(212)	− 7	9 50 21
11	Wp.	Feb. 14 - Apr. 29	4	(219)	− 9	9 50 18
12[f]	D	Mar. 10 - May 26	7	(230)	0	9 50 30
13	D	Apr. 4 - June 23	3	(230)	− 6	9 50 22
14[b]	D	Apr. 27 - June 23	3	(230)	− 4	9 50 25
15	Wf.	Feb. 14 - Apr. 29	3	(231)	− 9	9 50 18
16	W	Aug. 22 - Sept. 23	4	(235)	− 9	9 50 18
17[g]	W	Sept. 15 - Oct. 12	5	(289)	−39	9 49 38
18	Wp.	Mar. 15 - Apr. 16	3	(302)	− 7	9 50 21
19[a]	D	Mar. 15 - May 11	5	(302)	−10	9 50 17
20	Wf.	Mar. 15 - Apr. 16	4	(314)	− 6	9 50 22
21	D	Sept. 7 - Oct. 12	4	(345)	+13	9 50 47

Average..... 9h 50m 21s
Average without No. 17. 9 50 23

[a]This mark was sometimes seen as a projection from the south edge of the NEB and sometimes as the north base of a dark column across the *EZ*.

[b]This object grew larger as time passed.

[c]This projection was large in January and February.

[d]Perhaps this object and No. 3 are identical.

[e]This mark was more conspicuous from March 14 on.

[f]This mark grew less conspicuous after April 27.

[g]Sometimes transits of the *p* and *f* ends were averaged to obtain the longitude of the centre.

This current was the most active one on the planet until the *SEB* became very active late in the apparition. There was an abundance of dark projections and bright areas of greatly varying size and intensity along the south edge of the *NEB*.

It having been suspected with 1941-2 data that sometimes short-lived marks have abnormal periods of rotation,[3] necessarily approximative periods were deduced for 10 marks at this latitude followed from nine to 16 days in 1942-3. The association of brief durations and large drifts relative to System I is confirmed; for five of the marks had periods between $9^h\ 49.6^m$ and $9^h\ 50.1^m$, inclusive, though the remaining five were all between $9^h\ 50.4^m$ and $9^h\ 50.6^m$, inclusive. It is further of interest that three bright areas of periods $9^h\ 49.6^m$, $9^h\ 50.0^m$, and $9^h\ 50.0^m$ respectively disappeared as their drifts brought them near a dark projection, apparently without affecting the drift of the projection.

S part EZ and SEB.

No.	Description	Terminal Dates	Number Transits	λ_1 ♂	$\Delta\lambda/30$	Period
1[a]	D	Mar. 9 - May 17	5	(58°)	+42°	$9^h\ 51^m\ 26^s$
2[b]	Dp.	Apr. 9 - May 5	4	(125)	+74	9 52 9
3	D	May 11 - June 26	3	(154)	+28	9 51 7
4	Df.	Mar. 25 - Apr. 24	3	(221)	+76	9 52 12
5	Dp.	Mar. 25 - Apr. 24	3	(223)	+70	9 52 4
6[a,c]	D	Apr. 29 - May 27	3	(228)	+ 4	9 50 35
				Average.....		$9^h\ 51^m\ 36^s$

[a]Near May 21 these marks apparently coalesced.
[b]The *f* end of this dark section of the *SEB* decelerated very, very rapidly relative to System I between April 9 and 16.
[c]This object was seen on June 14 also.

The drifts above all refer to objects in the SEB_n, which was very active in March - June. Numerous dark spots and darker sections, as well as some bright gaps, existed in this belt; the detail was indeed too confused to permit many drifts to be deduced though it is probable that the markings were short-lived and that very large drifts in increasing longitude relative to System I were common. The space between the *SEB* components was also active late in the apparition; it contained both bright areas and dark

marks, the latter sometimes being columns connecting the components. No drifts could be deduced for this space. British observers followed well the early development of this *SEB* activity.[7] A few objects were seen in the *EB*, at the north edge of the SEB_n, and in the SEB_s; but drifts are undeterminable.

STrZ Disturbance.

No.	Description	Terminal Dates	Number Transits	λ_2 ☌ ☍	$\Delta\lambda/30^d$	Period
1	*Sp.* end	Aug. 25 - Sept. 23	5	(307°)	−16°	9h 55m 19s
2	*N* tip hump	Aug. 30 - Oct. 7	3	(323°)	−12	9 55 24
				Average		9h 55m 22s

A comparison of the last 1941-2 transits and the first 1942-3 transits indicates that the shorter period of the *f* end existent after April 7, 1942, caused a continuing rapid shortening of the Disturbance [3] near the 1942 conjunction until the motion of the whole of the short feature became somewhat faster than that of the *p* end had been in 1941-2. Such a faster motion was recorded in 1942-3. At any rate, the *p* end can be located by extrapolating its late 1941-2 drift-line through conjunction; the *f* end cannot be.

Red Spot and Hollow.

No.	Description	Terminal Dates	Number Transits	λ_2 ☌ ☍	$\Delta\lambda/30^d$	Period
1[a]	Dark column *StrZ*	Mar. 29 - July 1	6	(150°)	0°	9h 55m 41s
2[b]	*p* end Spot	Dec. 22 - Mar. 10	8	157	0	9 55 41
3[a]	Dark column *STrZ*	Apr. 6 - June 29	8	(178)	+3	9 55 45
4	*f* end Spot	Sept. 17 - Mar. 25	11	181	+1	9 55 42
				Average.....		9h 55m 42s

[a] This column lay at an end of the Hollow.

[b] The transits show such large internal discrepancies that either very gross errors were committed; or else, what is more probable, the drift was remarkably sinuous and oscillatory.

The average period of the centre of the Spot between the 1941 and 1943 oppositions (13 months apart) was 9h 55m 40s. Its

length early in 1943 was 24 degrees compared to 29 degrees during the first half of the 1941-2 apparition,[3] presumably because the probable deceleration of the *p* end late in that apparition[3] had shortened this feature. During 1942-3 the Spot moved much as in 1941-2; the *f* end had decelerated a little, and it may have previously accelerated near the 1942 conjunction. After the Hollow revived, it imitated the motion of the Spot except that the *f* end had a comparatively large decelerating motion, which increased the length of the Hollow from about 32 degrees near April 1 to about 40 degrees near July 1.

STrZ and N edge STB.

No.	Description	Terminal Dates	Number Transits	$\lambda_2 \sigma^{\rho}$	$\Delta\lambda/30^d$	Period
1[a]	D	Aug. 30 - Oct. 12	3	(21°)	− 2°	9h 55m 38s
2	D	Mar. 2 - Mar. 29	4	(45)	+14	9 56 0
3	D	Sept. 17 - Oct. 4	3	(198)	0	9 55 41
				Average.....		9h 55m 46s

[a]This object grew less conspicuous as time passed.

A perhaps more meaningful average of 9h 55m 40s results by using only No. 1 and No. 3, which were humps at the north edge of the *STB*. The slow No. 2 was a dark projection at the south edge of the SEB_s. Some detail was seen in the zone also; whether any of a number of dark columns observed to cross it can be identified with an end of the historical South Tropical Disturbance last certainly visible late in 1939[2,4,5] is pure guesswork.

STB and STeZ.

No.	Description	Terminal Dates	Number Transits	$\lambda_2 \sigma^{\rho}$	$\Delta\lambda/30^d$	Period
1	D	Jan. 10 - May 27	4	69°	−24°	9h 55m 8s
2[a]	D	Jan. 23 - Mar. 29	9	(196)	−27	9 55 4
3	Wf.	Mar. 15 - May 7	6	(252)	−24	9 55 8
				Average.....		9h 55m 7s

[a]A dark object seen on May 28 and June 4 falls close to the extrapolated drift-line.

No drifts resulted from the very few transits recorded of *STB* detail. In the *STeZ* there was much dark matter, which often

took the form of dark columns across the zone, and also some bright areas.

SSTB. A few transits of dark spots and darker sections in this belt supply no drifts, but an approximate period of $9^h\ 55.0^m$ is indicated for the accelerating p end of a darker section mentioned above. One can conjecture from small evidence that *STeZB* sections also had a period near that of the *STeZ*.

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110 N. Madison St.,
Upper Darby, Penna.
August 17, 1945.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

The A. Cressy Morrison Astronomical Prize

The following notice has been sent to the JOURNAL by the New York Academy of Science, as a part of the minutes of its annual meeting, held December 19, 1945.

The A. Cressy Morrison Committee announces, on behalf of Mr. Morrison, that he has offered an Astronomical Prize, in renewal of those awarded in recent years, in the sum of $500.00 for the paper, adjudged by the Council of the Academy, to be the most meritorious contribution on the subject of solar and stellar energy. In connection with this offer, the following statement has been prepared:

Understanding of the source of solar and stellar energy begins with Helmholtz's contraction theory (1854). As the primordial star contracts, the kinetic energy of the mass particles closing in under the force of gravity is transformed into heat energy. Whereas this is still believed to be cosmologically the first cause of stellar radiation, it has been realized since the end of the previous century that the process of contraction would run to its end in a time that is short as compared to the age of the earth; and, ever since this was realized, astronomers have been compelled to postulate that the Helmholtz contraction must be retarded and, for the major part of the life of the star, probably balanced by an internal pressure caused by energy that does not derive from kinetic energy. The way out of this difficulty was cleared theoretically (1905) by Einstein's law of the equivalence of mass and energy, although the exact mechanism whereby, under stellar conditions, matter would change into radiation, remained still a secret. The first laboratory transmutation of nitrogen into an isotope of oxygen by Rutherford (1917) opened the field of nuclear reactions which led to the experimental results; namely, that the mass lost in a nuclear reaction and the energy set free are in accordance with Einstein's law. By examining all possibilities of reactions that could take place under conditions prevailing in the sun, Bethe (1939) succeeded in singling out the one reaction that should, both as to the requirement of temperature and as to the availability of the elements involved, take place at the proper rate. This is the so-called carbon cycle whereby the energy liberated is equivalent to the mass defect of the helium atom as compared to four hydrogen atoms.

Prodigious progress has been made since the first A. Cressy Morrison Prize on the above subject was offered in 1926. It is, however, felt that the complete answer has not yet been given and many questions remain open. In the first place, no final model for the sun, properly satisfying the observed luminosity and the hydrodynamical considerations, has been published. Secondly, at best a start has been made on the problem of the so-called "red giants", "sub

dwarfs", and "white dwarfs". Through the continued interest of Mr. Morrison and his desire to stimulate further research in the subject, the above prize will be renewed for award in 1946.

Respectfully submitted,

F. S. H.

THE RETIREMENT OF DR. YOUNG

Dr. R. K. Young has resigned the position of Professor of Astronomy in the University of Toronto and Director of the David Dunlap Observatory. The absence of members of the staff on military duty during the long years of the War rendered the work of observing, hard to maintain, and the weather conditions of the winter of 1944-5 made conditions still more difficult. As a consequence Dr. Young's health suffered and he decided to retire and leave the work to younger hands. He hopes to spend some time in travel.

His successor as head of the Department and of the Observatory is Dr. Frank S. Hogg, who has been a member of the staff from the establishing of the Observatory. As all our readers know, Dr. Hogg is Assistant Editor of this JOURNAL and of the OBSERVER'S HANDBOOK. He is a past president of the Royal Astronomical Society of Canada, vice-president of the Toronto Centre of the Society, a member of the Council of the Royal Canadian Institute and a member of the Navigation Sub-committee of the National Committee on Aeronautics.

C. A. C.

MEETINGS OF THE SOCIETY

AT TORONTO

October 24, 1944.—The Society met at 8:00 p.m. in the McLennan Laboratory, University of Toronto; Miss R. J. Northcott in the chair.

Twenty-three persons were elected to membership in the Society, viz.:

Mr. John Arnett, 278 Dundas Street East, Toronto.
Mr. Paul Comision, 212 Medland Street, Toronto
Mr. F. K. Dalton 20 Wilgar Road, Toronto.
Mr. Owen E. Douglas, 11 Grenadier Road, Toronto.
Mr. Theodore Gormick, 720 Richmond Street West, Toronto.
Mr. Melvin Heidrich, 161 Kane Avenue, Toronto.
Mr. S. Heifetz, 327 Walmer Road, Toronto.
Miss Aileen Hiscock, 175 College Street, Toronto.
Mr. Lorne H. Jackman, c/o Y.M.C.A., Peterborough, Ontario.
Mr. Paul Kinsella, 34 Hadley Road, Toronto.
Mr. Vincent LaMantia, 382 Clinton Street, Toronto.
Mr. Alex. H. Macdonald, 84 Gerrard Street East, Toronto.
Mr. Robert D. McLeod, Jr., 185 Bay Front, Centre Island, Toronto
Mr. Robert Morham, 7 Walmsley Boulevard, Toronto.
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(and Seaforth, Ontario).
Mr. Bernard Sandbrook, 159 Wildwood Crescent, Toronto.
Mr. Gordon A. W. Squibb, 48 Main Street North, Weston, Ontario.
Mr. Seymour Steinhor, 22 Montrose Avenue, Toronto.

The program for the evening was a discussion on advisability of improving the calendar, under the general subject of "Our Calendar—Past, Present and Future."

Frederic L. Troyer outlined the history of the calendar. A synopsis follows:

"The calendar is the compass by which we chart our lives and activities, personal, national and international. Without a calendar our days would be a sorry mass of confusion.

"Perhaps the first calendar was devised when Neolithic Man lined up sticks or pebbles, or cut notches in trees to mark the passing of the days. Then Man became conscious of the moon as a time recorder, and found the period between similar phases a more convenient measure of time. Eventually

it was observed that 12 lunar months fell short of the yearly return of the seasons and in some years a 13th month was added to set things right. This became increasingly important as Man turned from a nomadic existence to an agricultural life and recognized that each season had its own particular weather and climate.

"The Egyptians, to whom it was of utmost importance to know exactly when the Nile would overflow its banks each year and leave the rich soil deposit on which their lives depended, learned that the reappearance of Sirius, the Dog Star, coincided almost exactly with the Nile floods, and noticed that this occurred at intervals of about 360 days. So they devised a calendar of 12 months of 30 days. Later, with increasing astronomical knowledge, they discovered their seasons were not so much dependent on Sirius as on the location of the sun, and they added five days, unattached to any month, to their year. They now had a year of 365 days, which began with the autumnal equinox, and which, though perfected before 4,000 B.C., is the direct forerunner of our modern calendar.

"The Roman calendar started with a 'year' of five lunar months, which later was increased to ten. In 713 B.C., Numa Pompilius, the reformer, undertook to harmonize the then current 10-month calendar with the sun and moon. He introduced two new months, Januarius placed at the beginning of the year, before March, and Februarius at the *end*, after December. In 452 B.C., the Roman magistrates changed this arrangement by placing February after January. Pompilius chose March 25, date of the spring equinox at that time, as the beginning of the Roman year and this continued until 153 B.C. In fact, it remained the accepted New Year's date over much of the world until comparatively recent times, and both the Bank of England and the Church of England still begin their fiscal years on March 25.

"Returning from his conquests, Julius Caesar brought from Egypt the famous astronomer Sosigenes and commissioned him to perfect a calendar for Rome. The old Roman solar-lunar calendar with its intercalated periods had become a political tool in the hands of the priests and demagogues, and this led to constant confusion. Caesar reformed this untrustworthy calendar into an ordered, scientific solar time system. The year was established at 365¼ days with a leap-year every fourth year. In this calendar the 'lucky' uneven months had 31 days, the 'unlucky' even months 30 days, except February which had 29 days with an extra one in leap years. Desiring to honour Caesar, the Roman senate changed the 'lucky' seventh month from Quintilis to Julius (July), and Augustus Caesar, his successor, filled with an exaggerated sense of self-esteem, persuaded his senators to honor him similarly, so Sextilis became Augustus. But as this was an 'unlucky' 30-day month, a day was taken from February and added to August. Now July, August and September, three successive months, had 31 days, so the senate increased the confusion by taking one day each from September and November and adding them to October and December. The result is that our present calendar has 90, 91, 92 and 92 days respectively in the four quarters, an irregularity which has increasingly become a nuisance in modern business where comparison of statistics and reports is of great importance.

"In 321 A.D., Constantine the Great abolished the divisions of the Roman month—Kalends, Nones and Ides—in favour of a seven-day week, which for some time had been unofficially observed by the early Christians. At this time also, the Church, after long argument, set the date of Easter on the first Sunday after the first full moon following the vernal equinox, and since then Easter has wandered over a period of 35 days.

"No change was effected in the calendar for another twelve centuries, until, in 1582, the Gregorian calendar was introduced to overcome the slight difference between 365¼ days and the real period of the earth's rotation which had caused the calendar to fall out of step with the seasons. Actually the calendar had run ahead 14 days, but only 10 were dropped, the other four being accounted for by setting March 21 instead of the 25th, as date of the equinox. The calendar was now adjusted so that 3,323 years would have to pass before one day too many would have accumulated."

Mr. J. Royden Gilley, Chairman of the Toronto Committee of the World Calendar Association, spoke on "The Question of Calendar Reform". The Gregorian reform had failed, he said, to correct some of the most glaring and wasteful defects in the calendar. Any reform should keep the good features, making the fewest and simplest changes consistent with improvements necessary for modern needs. Several proposals had been made for calendar revision, and had been carefully studied by committees of the League of Nations, the International Astronomical Union, governments and chambers of commerce in many nations.

One proposal, widely publicized several years ago, was a 13-month calendar with each month having four weeks of seven days, and one intercalary day in ordinary years, two in leap years. This had one serious disadvantage—it is not divisible into halves and quarters. Realizing this drawback to business, although the 13-month calendar was personally preferred by many astronomers, the International Astronomical Union's commission on calendar revision a few years ago came out strongly in favor of an alternative plan, a 12-month improved calendar which would make few alterations in the present calendar, but achieve the desired four quarters with an equal number of days. This plan is now known as the World Calendar. Both the World Calendar and the proposed 13-month revision would begin each year on a Sunday, the 365th day in each year (and 366th in leap years) becoming a holiday outside the regular system of weeks.

The time had come, Mr. Gilley said, when improvements in the calendar were long overdue. At present we can have 28 different kinds of months; beginning on any one of seven days of the week and of 28, 29, 30 or 31 days' length. The week-days vary from 24 to 27, and some months have four Sundays, other five.

Adoption of the World Calendar, he said, would provide all the desired improvements without the drastic upheaval involved in the 13-month plan. Each year would be the same, the quarters equal in length, each month would have 26 week-days, and anniversaries would always come on the same day

of the week. The World Calendar would give 31 days to the first month of each quarter, 30 to the other eight months. Thus each quarter would consist of 91 days or 13 full weeks, and the inequalities between months reduced from three days to one.

Industry would benefit greatly because financial statements and other statistics could be co-ordinated; labour would benefit through regulated holiday periods and equal number of work days each month, and similar benefits would be felt by governments, law, financial and educational organizations.

"The next year in which the World Calendar can conveniently be put into operation is 1950—and it is not too early now to get ready to make our governments aware that many of us are genuinely interested in this subject and in seeing adoption of this plan—A New Calendar for a New World."

Following a general discussion in which the speakers answered a number of questions from the audience, and several members expressed their views on the subject of calendar revision, the meeting was adjourned.

FREDERIC L. TROYER,
Recorder.

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